ARO-D 8677.28-P

AD 749287

SEMI-ANNUAL TECHNICAL SUMMARY OF RESEARCH OF AEROPHYSICS INSTITUTE FOR STRATEGIC TECHNOLOGY

for the period ending 29 February 1972

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 1442, Amendment 2
Program Code 9E30

D D C
RECEIVED
SEP 25 1972
B

SEE AD744533

PIBAL
Report 72-A

for
U.S. Army Research Office-Durham
Contract No. DAHCO4-69-C-0077

POLYTECHNIC INSTITUTE OF BROOKLYN

30

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Polytechnic Institute of Brooklyn 333 Jay Street Brooklyn, New York 11201	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

SEMI-ANNUAL TECHNICAL SUMMARY OF RESEARCH OF AEROPHYSICS INSTITUTE FOR STRATEGIC TECHNOLOGY

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Semi-Annual Technical Summary for period ending 29 February 1972

5. AUTHOR(S) (First name, middle initial, last name)

Principal Investigator: Martin H. Bloom

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
		0

8a. CONTRACT OR GRANT NO. DAHC04-69-C-0077	9a. ORIGINATOR'S REPORT NUMBER(S) PIBAL REPORT NO. 72-A
b. PROJECT NO. ARPA Order No. 1442, Amendment 2	
c. Program Code No. 9E30	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Advanced Research Projects Agency and U.S. Army Research Office-Durham

13. ABSTRACT

This report contains a description of the technical problem areas and accomplishments achieved during the reporting period. In addition, a complete list of publications, presentations, lectures, etc. is included and the personnel associated with the program are listed. The research projects are in the general subject areas of fluid and plasma dynamics. The work described was carried out under an ARPA contract, Order No. 1442, Amendment 2.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Plasmas Numerical methods Turbulence Raman Scattering Liquid film cooling Flow diagnostics						

SEMI-ANNUAL TECHNICAL SUMMARY OF
RESEARCH OF AEROPHYSICS INSTITUTE
FOR STRATEGIC TECHNOLOGY

for the period ending 29 February 1972

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 1442, Amendment 2
Program Code 9E30

Date of Contract: 1 September 1969

Expiration Date: 30 June 1972

PIBAL Report 72-A

for
U.S. Army Research Office-Durham
Contract No. DAHC04-69-C-0077

Submitted by: Martin H. Bloom
Principal Investigator
Director of Gas Dynamics Research
Dean of Engineering

POLYTECHNIC INSTITUTE OF BROOKLYN

333 Jay Street, Brooklyn, N. Y. 11201

ic

ACKNOWLEDGMENT

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by U.S. Army Research Office-Durham, Box CM, Duke Station, Durham, North Carolina 27706, under Contract No. DAHCO4-69-C-0077.

ABSTRACT

This report contains a description of the technical problem areas and accomplishments achieved during the reporting period. In addition, a complete list of publications, presentations, lectures, etc., is included and the personnel associated with this program are listed. The research projects are in the general subject areas of fluid and plasma dynamics. The work described was carried out under an ARPA contract, Order No. 1442, Amendment 2.

I. INTRODUCTION

The Polytechnic Institute of Brooklyn is conducting an interdisciplinary program involving both theoretical and experimental studies in the areas of aerodynamics, plasma dynamics, and turbulence. In particular, those aspects are dealt with which are directly applicable to the immediate and long range interests of the ARPA Strategic Technology Office. Laboratory simulations, experimental devices and comparison of results with observed flight behavior are under consideration. Generation of new ideas and the review and evaluation of research performed by others in the professional community is also a significant part of the research effort.

In addition to the research studies briefly summarized in the following section, the investigators are engaged in ARPA committees and discussions and normally participate in the various workshops and meetings pertinent to the overall program.

II. RESEARCH PROJECTS

In this section, the various technical aspects of the invididual research projects are discussed. In addition to a description of the task, the investigators, including faculty and students, and the current effort and major accomplishments to date are described. The various research areas are listed here for reference:

A. Flow Diagnostic Development

B. Electron-Beam Diagnostics of Turbulent Plasmas

C. Vortex Structures and Turbulence

D. Laser Brightness Experiment

E. High Altitude Plume Diagnostics

A. Flow Diagnostic Development

Investigators: Professor S. Lederman and Mr. J. Bornstein

Technical Program and Accomplishments:

As indicated in the previous semi-annual report covering the period ending August 31, 1971, the emphasis of this part of the program was shifted from the electrostatic probe diagnostic techniques to the electron beam density probes and Raman scattering techniques. The electron density probe was used in conjunction with electrostatic probes, both flush and cylindrical to verify a proposed technique of flow field tracing developed in our laboratory. This proposed technique afforded a means of flow field tracing, provided the medium is slightly ionized, chemically frozen and nondiffusive. The results of this research are given in Ref. 1.

The problem of interaction of a shock produced electron precursor and a microwave signal was concluded. The results will be published soon in The Physics of Fluids[2]. A conclusion was also brought to the investigation concerned with the breakdown of open-ended microwave waveguide antennae in different gases, as a function of pressure pulse

power, pulse duration and pulse rate. The results are given in Ref. 3.

The work concerned with the applicability of the Raman scattered radiation to flow field diagnostics is in progress. Upon construction of the proper apparatus, an attempt has been made to obtain the resonant Raman scattered radiation. Preliminary results on vapor iodine are very encouraging. While it was possible to utilize for this purpose the available Q-switched Ruby laser, gases other than I_2 also require other laser wavelength. The results of this preliminary work in the form of a report is in preparation.

In another aspect of the applications of the Raman effect as a diagnostic tool in fluid dynamic research, a simple method for the determination of some of the molecular invariants of species of interest has been developed. The results of this work in the form of a report is also in preparation.

At present, work is proceeding on the problem of entrainment of a fireball. Here the applicability of the remote Raman diagnostic technique is being investigated.

Some preliminary experiments are being concluded utilizing a shock tube.

References:

1. Avidor, J.M. and Lederman, S.: Flow Field Diagnostics in Rarefied Slightly Ionized Flow. PIBAL Report No. 71-18, June 1971; also, paper published in the Proceedings of the 14th Israel Annual Conference on Aviation and Astronautics, March 1972.
2. Lederman, S. and Dawson, E.F.: Effect of Microwave Radiation on a Shock-Produced Electron Precursor. PIBAL Report No. 71-13, May 1971 (to appear in The Physics of Fluids).
3. Dawson, E.F. and Lederman, S.: Pulsed Microwave Breakdown in Gases With a Low Degree of Preionization. (In preparation).

B. Electron-Beam Diagnostics of Turbulent Plasmas

Investigator : Professor E. Levi

Technical Program and Accomplishments:

The objective is to investigate the feasibility of using an electron beam as a diagnostic tool for plasmas. Specifically, it is expected that the electron beam may be used to determine the frequency spectrum of local fluctuations or turbulence in an ionized medium. The final goal is the development of the method and the determination of its range of applicability.

The studies are carried out theoretically and experimentally.

1. Theory

The current status of the program follows: The theory based on an idealized model consisting of a lateral infinite cold beam-warm plasma system, has been completed and forms the Ph.D. dissertation of Mr. Ray Eichler. An abstract has been accepted for publication in the Journal of Applied Physics (date is yet not known)[1]. The dependence of the beam-modulation on the transverse propagation constant and frequencies of the turbulent plasma function has been explained. At present the case of a finite beam is being investigated.

2. Experimental Work

a. r.f. and P.I.G. Discharges

The experimental studies of r.f. generated plasmas and PIG discharges proved to be too complicated in view of the uncontrollable and unknown turbulence characteristics. Hence, further quantitative studies will be carried out on the thermionically heated, low-voltage arc discharge.

b. Mock-up measurements

A mock-up of the microwave circuit and the electron gun was constructed to test new configurations of these elements. Instead of

microwave cavities two helices were used; and instead of a TWT electron gun, a CRT gun was used. We were unable to fully activate the cathode and so the beam current was too small to make any meaningful measurements.

Further work on the mock-up was postponed in favor of the work discussed in the succeeding paragraphs.

c. Modification of the beam plasma device (BPD)

In order to facilitate studies over wide frequency ranges two helix-couplers mounted on either side of the plasma chamber were added to the BPD. This meant that additional vacuum tight, microwave feed-throughs were required, and some minor modifications of the dewar sections were made to provide space and mounts for the helices.

d. Activation of the electron gun cathode and the discharge cathode

The vac-ion pump which maintains a vacuum in the electron gun section was turned off (by some unknown person) and the pressure rose to an estimated value of 10^{-2} - 10^{-3} Torr. This required a slow reprocessing of the cathode which had been activated previously. The electron gun cathode was reactivated successfully and fortunately, it was not seriously damaged by the rise in pressure.

The discharge cathode is being processed now.

e. Microwave-beam measurements

The results of the preliminary measurements are summarized below:

1. The radiation of microwave energy into the vacuum chamber and the pick-up of this energy by the helix is at least 20 db greater* than for the cavities.

2. The coupling coefficient of the cavity to the electron beam is at least 6 db greater than the coefficient for the helix.

*When a relatively large signal is processed by a Polarad Receiver, the arc circuit operates to prevent making reliable gain measurements using the standard detector system.

3. A microwave signal coupled to the beam using a cavity is readily detected using the output helix. If the input helix is used to couple microwave energy to the beam, too much microwave energy is radiated to obtain a reliably detected signal from the beam*.

4. The helices will be shielded when the BPD is disassembled for servicing.

f. <u>Work for the next period</u>

1. Complete processing of discharge cathode.

2. Make quantitative measurements of the gain characteristics of the BPD as a function of frequency and plasma density using both microwave circuits (output helix and output cavity).

<u>References:</u>

1. Eichler, R., Hutter, R.G.E. and Levi, E.: <u>Interaction Between an Electron Beam and a Turbulent Plasma</u>. Journal of Applied Physics (date as yet unknown).

2. Semi-Annual Technical Summary of Research of Aerophysics Institute for Strategic Technology (for period ending 31 August 1971), PIBAL Report 71-B.

C. <u>Vortex Structures and Turbulence</u>

<u>Investigator</u>: Professor P.M. Sforza

<u>Technical Program and Accomplishments:</u>

Wake-like flows often exhibit orderly vortex superstructures or "streets" which strongly affect the entrainment characteristics of the wake region. These structures generally precede the breakdown of the initially laminar flow to the turbulent state. The analysis for vortex streets previously developed under this program is being applied to wake-like flows in order to study the entrainment mechanism and the process of transition.

Two experimental investigations concerning such flow fields are

presently being pursued: one involves the flow behind an axisymmetric cylinder whose axis is coincident with the free stream direction and the other covers the flow over leading edge protuberances. In the former case the body may be heated so that the effects of self-induced density gradients may be studied. Preliminary results show that the heated wake exhibits "flattening" similar to that observed for wakes behind axisymmetric bodies in density stratified fluids. Such "flattening" was observed in heated free jets in past studies performed under this contract[1]. The latter case, flow behind leading edge obstacles, is aimed at providing further information on the effect of vortex structures on boundary layer flows. The primary results are found to be an instigation of transition to turbulence and increased skin friction in the vicinity of the vortex structures. This suggests that at high speed conditions there will be an analogous rise in heat transfer in the affected regions.

Another area in which vorticity and turbulence play a major role is that of fireball behavior. The basic fluid dynamic features of vorticity generation in such flow fields is under investigation. The intent is to suitably define the problem in fluid dynamic terms so that more appropriate schemes for laboratory investigation may be generated.

<u>References:</u>

1. Trentacoste, N.P. and Sforza, P.M.: <u>Studies in Homogeneous and Nonhomogeneous Free Turbulent Shear Flows.</u> PIBAL Report No. 69-36, September 1969.

D. <u>Laser Brightness Experiment</u>

<u>Investigators:</u> Dr. W. Walter and Professor J. LaTourrette

<u>Technical Program and Accomplishments:</u>

The brightness (watts-cm^{-2}-steradian^{-1}) of high power lasers, such as gas dynamic and chemical lasers, is greatly reduced from the

optimum performance of diffraction-limited output operation. Turbulence within these laser media is a likely and sufficient cause to explain the poor performance. However, a suggestion has been put forth that the high gain of these laser media also contributes to the output beam spread. By using a visible high-gain metal-vapor laser, namely a copper vapor laser, as a model for the infrared gas-dynamic and chemical lasers, the effects of high-gain and turbulence can be uncoupled and separately investigated in the more tractable visible spectral region.

Preliminary results[1] which we have obtained with the copper vapor laser have shown that nearly diffraction-limited performance can be achieved by using a high-loss resonator with this pulsed, high-gain laser medium. The theory of high-loss resonators[2] indicates that high-gain laser media are particularly suited to the use of high-loss resonator geometries for obtaining near diffraction-limited performance.

We are using the existing metal-vapor laser facility at PIB to study the output characteristics of a high-gain laser medium and to determine how the output is degraded by the introduction of controlled amounts of turbulence. Two cells are placed within the optical resonator. One cell is filled with the active gain medium which consists of an electric discharge in copper vapor. The second cell is used to introduce a controlled amount of turbulence within the optical cavity. The effect of the addition of turbulence to various optical resonators can then be investigated.

The first experiments will utilize an existing flow generator to introduce flowing gases within the optical cavity of a copper vapor laser. The flow introduced will be transverse to the axis of the optical cavity. The flow generator consists of seven small, 1 mm diameter tubes placed horizontally one above another, 5 mm between centers, in a vertical line within a larger 10 cm diameter tube. Separate flows can be introduced in the manifold of smaller tubes and in the larger surrounding tube.

Previous work with this flow generator showed that when the existing flow rates are made equal, then there is very little mixing between the flows for ~10 cm downstream. Further downstream, mixing between the streams occur. This situation can be demonstrated by adding smoke to the gas flow through the smaller tubes. When the laser axis is placed close to the orifices of the tubes (and transverse to the stream flow), well-defined bands of flowing gas are introduced into the laser's optical cavity.

Three types of experimental conditions can be produced by the flow generator.

1. Introduction of different gases into the smaller and larger tubes (such as helium and nitrogen or CO_2) will produce bands or a Venetian blind pattern with alternating indices of refraction.

2. Introduction of smoke into the gas flow within the smaller tubes will add scatterers within the optical cavity also in a banded pattern.

3. As the flow generator is moved away from the laser axis or as the flow velocities are changed, the flow conditions within the laser cavity will change from a streamline or laminar flow to a turbulent flow.

The output power, beam quality and beam divergence of the copper vapor laser will be examined under the three experimental conditions described above. This will be carried out for a conventional plane-parallel Fabry-Perot optical cavity and repeated for a high-loss resonator. In this way we expect to clarify the effect of intracavity turbulence on the output beam properties of the laser. We also expect to determine whether the deleterious effects can be ameliorated by the type of optical resonator employed.

During this reporting period the experiments have been planned and the equipment has been assembled. The experimental work will begin during the next reporting period.

<u>References:</u>

1. Chimenti, R. and Walter, W.T.: <u>Coherence Properties of the Pulsed</u>

Copper Vapor Laser. Bulletin American Physical Society, 16, 41, (1971) and Progress Report No. 35 to Joint Services Technical Advisory Committee, Report R-452.35-70, Contract F44620-69-C-0047, page 30, September 1970.

2. LaTourrette, J.T. et al.: Mode Selection Investigation. Interim Report No. 2, Contract AF33(615)-3888.

E. High Altitude Plume Dynamics

Investigators: Professor S.G. Rubin and Mr. J. Kelly

Technical Program and Accomplishments:

During the past year, an investigation concerning an evaluation of the flow field associated with a retro-plume interaction has been initiated. The basic flow configuration has previously been established in experiments and simple analysis and it is our intent to carry out a combined theoretical and experimental program so that the flow properties, including pressure and temperature levels, can be determined for a wide range of stream and jet conditions.

The aim of the theoretical analysis is to present results that are easily obtainable without the need of complex computer programs which may not be readily obtainable or easy to duplicate. It is recognized that time-dependent programs do exist and may be capable of calculating the retro-plume flow field in reasonable computer times so that our aim is an engineering approach that can provide the desired information (1) in an analytic form so that specific effects can be evaluated systematically; (2) can be used by other investigators who do not have access to, or cannot deal with the intricacies of a time-dependent program; and (3) may be useful as an analytic solution in the further evaluation of viscous and far field effects. Typical results for the bow shock region have already been completed. The details of the analysis are not presented here, but are typical of thin shock layer theories on blunt bodies, and

consider different expansions for the shock layer, contact surface layer and inner jet flow. The triple point interaction is to be included in the final analysis.

A simple experimental program is planned to establish the validity of the analysis. Flow field visualization and certain pressure measurements, in particular in the dead air recirculation or core region, will be included as they provide a simple and definitive means of comparison. More sophisticated measurements are under consideration and will be considered if deemed desirable.

III. SUMMARY OF RESEARCH PUBLICATIONS

A. Published Articles

C.H. Shih and E. Levi, "Effect of Collisions on Cold Ion Collection by Means of Langmuir Probes". AIAA Journal, Vol. 9, No. 9, pp. 1673-1680, September 1971.

Langmuir probes are extensively used to sample plasma densities. However, the interpretation of probe data is well established only for the limiting cases of collisionless and collision-dominated plasmas. A transitional regime prevails in some fluid-dynamic situations and electrical discharges in which the ions are colder than the electrons. A simple theory which accounts separately for the effects of collisions between charged particles and collisions with neutrals is presented. When the theory is applied to recent experimental data taken with cylindrical as well as spherical probes, the electron densities calculated from the probe measurements by using the present theory agree within 10% with those inferred from existing numerical solutions, an empirical formula, and microwave cavity data.

C.H. Shih and E. Levi, "Determination of the Collision Parameters by Means of Langmuir Probes"*, AIAA Journal, Vol. 9, No. 12, pp. 2417-2421, December 1971.

The current collected by Langmuir probes in the ion saturation regime is affected by collisions among ions and with neutrals. This effect depends not only on the Debye length and the various mean free paths involved, but also on the geometry, size, and biasing potential of the probes. Two or more independent measurements thus afford means for determining the collision parameters and related quantities, such as

*This work is partially sponsored by the Joint Services Electronics Program, Contract F44620-69-C-0047.

the ion temperatures, the chemical composition of the plasma, and the density of the background gas. Good agreement is obtained between theory and experimental data taken in quite distinct physical situations, by using a hypersonic shock tunnel and a laser discharge. The method presented here could be applied to the determination of ion-neutral collision cross sections in the transition region between the D and E layers of the ionosphere.

C.H. Shih and E. Levi, "Transient Performance of Negatively Biased Langmuir Probes",* AIAA Journal, Vol. 10, No. 1, pp. 104-110, January 1972.

Negatively biased Langmuir probes constitute one of the most common tools of gaseous plasma physics and are increasingly often used in time-varying situations. To determine the dynamic behavior of Langmuir probes, analytical expressions are derived for the response of planar and cylindrical sheaths to large amplitude and sudden changes in the biasing potentials. It is found that the speed of response depends on the sign of the charge, this asymmetry being particularly pronounced with planar probes. The analysis also leads to equivalent circuits describing the dynamic response of probes in the collisional, as well as the collisionless regimes. These circuits have direct application in analogue simulation and give valuable assistance to the designer of computerized data processing. They show that the time constants characterizing the probe response can exceed $1/\omega_{pi}$ by one order of magnitude and that, at frequencies below $10^{-2}\omega_{pi}$, a frequency range of great interest for the study of turbulence, the dynamic performance of the probes can be approximated by a succession of quasi-steady states. Expressions are derived which relate the mean and the variance of the

*This work is partially sponsored by the Joint Services Electronics Program, Contract F44620-69-C-0047.

probe current to the auto and cross correlations of fluctuations in density, temperature, and potential. Particular attention is given to the two cases in which (a) the density fluctuation is overriding and attains large amplitude, a likely occurrence with slightly ionized gases, and (b) the level of fluctuations is low, but more than one type is simultaneously present. Finally the theoretical findings are examined in the light of experimental evidence reported in the published literature. Although qualitative agreement is good, the simplicity of the analytical model and the inadequate characterization of the experimental conditions, often limit the quantitative agreement to one order of magnitude.

H.W. Friedman and E. Levi, "Plasma Shielding", The Physics of Fluids, Vol. 13, No. 4, pp. 1049-1054, April 1970.+

Necessary and sufficient conditions are established for the shielding of current-carrying plasmas by means of space charge sheaths. These conditions reduce to Bohm's shielding criterion in the particular case of zero current and, in general, are consistent with measurements obtained by means of Langmuir probes and their current interpretation.

B. Presentations at Technical Meetings

R.J. Cresci and J. Starkenberg are authors of a paper entitled "Liquid Film Cooling on Hypersonic Slender Bodies", which was presented at the XXII Congress of the International Astronautical Federation, held in Brussels, Belgium, September 20-25, 1971.

R.J. Cresci presented a paper entitled "Experimental and Analytic Performance of the Slingshot Pilot Facility", co-authored by J. Librizzi, D. Landsberg and M.H. Bloom, at the AIAA 10th Aerospace Sciences Meeting, held in San Diego, California, January 17-19, 1972.

+This item omitted from previous report.

C. P.I.B. Reports, Dissertations, and Books

G. Moretti, "Complicated One-Dimensional Flows", PIBAL Report No. 71-25, September 1971.

J. Bornstein and S. Lederman, "Effect of Collisions on Electrostatic Probe Measurements", PIBAL Report No. 71-32, November 1971.

G. Moretti and M. Pandolfi, "Entropy Layers"*, PIBAL Report No. 71-33, November 1971.

E. Levi, R.G.E. Hutter and H. Farber, "Electron Beam Diagnostics of Turbulent Plasmas", informal progress report covering period to February 1972.

---

*This work is partially sponsored by Office of Naval Research under Contract No. N00014-67-A-0438-0009.

IV. ARPA-RELATED ACTIVITIES, LECTURES AND CONSULTANTS

A. ARPA-Related Activites

Dean Martin H. Bloom is a member of the Atomic and Molecular Physics Panel of the Institute for Defense Analyses (IDA); Associate Editor of the Journal of Ballistic Missile Defense Research, published by IDA for ARPA; and is a consulting member of the Plume Technology Working Group, Joint Army-Navy-Air Force. He was awarded the Army's Outstanding Civilian Service Award for duties performed while serving as a consultant to the Safeguard Research, Development, Test and Evaluation Directorate during the period March 1963 to July 1971, and in recognition for his proposal evaluations, reviews and committee work on the Sprint and Spartan missile subsystem development program.

Participation at meetings relevant to the program:

Martin H. Bloom attended the Workshop and Summary Analysis Meeting on RMP-B On-Board Experiments, held at Bell Laboratories, Whippany, New Jersey, September 14-15, 1971; and participated in the ARPA Turbulence Modelling Workshop, held at the National Bureau of Standards, Boulder, Colorado, October 18-19, 1971.

Robert J. Cresci and Martin H. Bloom attended the Workshop on Flow Condensation for ABMDA, held in Huntsville, Alabama, January 6, 1972.

Martin H. Bloom visited ARPA on January 11, 1972 to serve on a committee appointed to review and assess the technical status of ARPA's Surface Effect Takeoff and Landing System Program.

Samuel Lederman, Martin H. Bloom, Enrico Levi, and Robert J. Cresci were invited to attend the briefing for the ARPA/STO Institutes, held at IDA, January 20-21, 1972. Dr. Levi also visited the Naval Research Laboratory.

Martin H. Bloom was invited to attend the Reentry Analysis and Prediction Technical Direction Meeting, held at AVCO-Everett Research

Laboratory, Everett, Massachusetts, January 27, 1972.

Samuel Lederman participated in the ARPA Workshop held at the Aerospace Corporation, San Bernardino, California, February 17, 1972.

Robert J. Cresci attended the ARPA Workshop on Plume Physics, held at TRW Systems, Inc., Redondo Beach, California, February 27-March 2, 1972. At the workshop he gave a presentation on "High Altitude Plume Dynamics" by S.G. Rubin and J. Kelly.

B. Lectures

September 1971

Prof. S. Ostrach Case Western Reserve University	Blood Flow in the Large Vessels

October 1971

Dr. S. Maslen RIAS, Martin-Marietta Corp.	Inviscid Hypersonic Flow

November 1971

Prof. D. Turcotte Cornell University	Solid State Convection in the Earth's Mantle
Dr. George Lamb, Jr. United Aircraft Corp.	Higher Conservation Laws in Coherent Optical Pulse Propagation Prop

December 1971

Prof. S. Lederman Polytechnic Institute of Brooklyn	The Raman Effect and Some Applications In Research
Prof. A. Hessel Polytechnic Institute of Brooklyn	Blazed Diffraction Gratings
Prof. Y.B. Yu Polytechnic Institute of Brooklyn	Theory of the Discriminant in Lamb Dip Spectroscopy
Prof. S.R. Barone Polytechnic Institute of Brooklyn	Short Pulse Propagations in Resonant Media
Prof. H.L. Bertoni Polytechnic Institute of Brooklyn	Microwave Network Approach to Guided Acoustic Waves

Dr. Y.V. Gulyaev Academy of Sciences of USSR	Acoustic-Electronics in the USSR
Mr. S.T. Peng Polytechnic Institute of Brooklyn	Linear Parametric Approximation for Nonlinear Wave Interactions
Prof. L. Levey Polytechnic Institute of Brooklyn	Local Properties of Evanescent Fields Near Caustics

<u>January 1972</u>

Prof. E.S. Cassedy Polytechnic Institute of Brooklyn	Status of Research in the U.S. and Western Europe on Laser-Heated Plasmas for Controlled Fusion
Prof. G. Moretti Polytechnic Institute of Brooklyn	Nonlinear Wave Problems in Fluid Dynamics
Prof. S.J. Maurer Polytechnic Institute of Brooklyn	Quasi-Optical Study of Radiation from a Dielectric Wedge
Dr. M. Szalek Polish Academy of Sciences	Some Error Bounds for Scattering and Radiation Problems
Mr. S.T. Peng Polytechnic Institute of Brooklyn	Propagation of Waves in Nonlinear Dielectrics

<u>February 1972</u>

Dr. M. Pandolfi Politechnico di Torino	Entropy Layers on Blunted Cones
Prof. E.S. Cassedy Polytechnic Institute of Brooklyn	Absolute Instabilities in Parametric Phenomena
Prof. E. Mishkin Polytechnic Institute of Brooklyn	Analytical Theory of Propagation of Ultra-Short Pulses
Dr. B. Rulf Tel Aviv University	Asymptotic Theory of Guided Waves

V. PERSONNEL ASSOCIATED WITH THE RESEARCH PROGRAM

Martin H. Bloom	Principal Investigator Director of Gas Dynamics Research Dean of Engineering
R.J. Cresci	Professor
H. Farber	Associate Professor
R.G.E Hutter	Professor
J.T. LaTourrette	Professor
S. Lederman	Associate Professor
E. Levi	Professor
G. Moretti	Professor
P.M. Sforza	Associate Professor
W. Walter	Research Scientist

ADDENDUM to the
SEMI-ANNUAL TECHNICAL SUMMARY OF
RESEARCH OF AEROPHYSICS INSTITUTE
FOR STRATEGIC TECHNOLOGY

for the period ending 29 February 1972

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 1442, Amendment 2
Program Code 9E30

Date of Contract: 1 September 1969

Expiration Date: 30 June 1972

PIBAL
Report No. 72-A

for
U.S. Army Research Office-Durham
Contract No. DAHC04-69-C-0077

Submitted by: Martin H. Bloom
Principal Investigator
Director of Gas Dynamics Research
Dean of Engineering

POLYTECHNIC INSTITUTE OF BROOKLYN

333 Jay Street, Brooklyn, N. Y. 11201

POLYTECHNIC INSTITUTE OF BROOKLYN

Department of Aerospace Engineering
and Applied Mechanics

ADDENDUM

SEMI-ANNUAL TECHNICAL SUMMARY OF
RESEARCH OF AEROPHYSICS INSTITUTE
FOR STRATEGIC TECHNOLOGY

for the period ending 29 February 1972

PIBAL Report No. 72-A

II. RESEARCH PROJECTS

A. Flow Diagnostic Development

Investigators: Professor S. Lederman and Mr. J. Bornstein

Defense Significance:

The development of the different diagnostic techniques of flow field determination is not only of major importance for the understanding of the basic phenomena accompanying reentry, but also is significant in identifying reentry vehicles.

The Raman scattering technique properly developed and applied may render information rarely obtainable by other means. The ability to identify different species simultaneously, instantaneously, remotely and single-endedly provides a means of instantaneous differentiation between decoy and armed vehicles, by observing the species in the wake. The Raman diagnostic technique provides the means for shifting the observable radiation into a convenient region of the spectrum, thus avoiding interferences

in certain instances. The detection of enemy concentrations, of well-hidden supply dumps, and their movement in heavily wooded areas or other locations which are difficult to observe from the air, could be accomplished and the type of supply depot determined. While the normal Raman effect may provide detectable signals at relatively short distances, the resonant Raman effect could provide signals up to 5 orders of magnitude higher, thus permitting observation from greater distances of the same minimal concentrations of the observed species.

B. <u>Electron-Beam Diagnostics of Turbulent Plasmas</u>

<u>Investigator</u>: Professor E. Levi

<u>Defense Significance:</u>

Plasmas are the significant part of many devices in fusion, lasers, propulsion devices, etc. Diagnostic tools for the study of the behavior of such plasmas are a significant part of plasma research.

C. <u>Vortex Structures and Turbulence</u>

<u>Investigator</u>: Professor P.M. Sforza

<u>Defense Significance:</u>

The interaction between concentrated vortex structures and boundary layer type flows markedly affect transition trends, stress field development, entrainment efficiency and three-dimensionality. These effects are particularly important in predicting the flow around and in the wake of submerged bodies. Awareness of these phenomena may aid in tailoring such bodies to produce desired downstream characteristics.

An additional consideration for such flow fields is the effect of local density gradients either normally present in the ambient or self-generated by, for example, dispersal of waste heat from the submerged body.

The investigation of fireball phenomena needs no elaboration here. Furthermore, the basic study of vorticity generation in such flow fields will be of general fluid dynamic interest.

D. <u>Laser Brightness Experiment</u>

<u>Investigators</u>: Dr. W. Walter and Professor J. LaTourrette

<u>Defense Significance:</u>

The utility of high-power gas dynamic and chemical lasers will depend on their output brightness, or on how closely their operation approaches diffraction-limited performance. By using a visible high-gain metal-vapor laser as a model for the infrared gas-dynamic and chemical lasers, the effects of high-gain and turbulence can be uncoupled and separately investigated in the more tractable visible spectral region. The results of this study will directly bear on the evaluation of chemical and gas dynamic laser for ballistic missile defense.

Furthermore, the maximum transmission of light through water occurs in the green portion of the visible spectrum. At present there is a deficiency of efficient, high-power light sources in the green. The output of the pulsed copper vapor laser is at 5106Å which is at the maximum of the water transmission band. The development of this laser for use with gated viewing systems

could significantly increase the present limited optical ranges under water.

E. High Altitude Plume Dynamics

Investigators: Professor S.G. Rubin and Mr. J. Kelly

Defense Significance:

Knowledge of the spectrum and intensity of observables in rocket plumes and retro plumes facilitates detection for early warning and other defensive ballistic missile missions. To this purpose analysis will provide detailed flow field distributions as well as insight into rocket-rocket plume scaling laws.